

What Is Claimed Is:

1 1. A method of closed-chest surgical intervention within an internal cavity
2 of a patient's heart or great vessel, the method comprising:
3 establishing cardiopulmonary bypass;
4 arresting the patient's heart;
5 viewing an internal portion of the patient's chest through a scope extending
6 through a percutaneous intercostal penetration in the patient's chest;
7 forming an internal penetration in a wall of the heart or great vessel using
8 cutting means introduced through a percutaneous intercostal penetration in the patient's
9 chest; and
10 introducing an interventional tool through a percutaneous intercostal penetration
11 and through the internal penetration to perform a surgical procedure within the internal
12 cavity under visualization by means of said scope.

1 2. The method of claim 1 wherein the patient's heart is arrested by
2 occluding the patient's aorta between the patient's coronary arteries and the patient's
3 brachiocephalic artery with an expandable member on a distal end of an endovascular
4 catheter, and perfusing the patient's myocardium with cardioplegic fluid.

1 3. The method of claim 1 wherein the interventional tool is introduced
2 through a cannula positioned in a percutaneous intercostal penetration.

1 4. The method of claim 1 wherein the surgical procedure comprises
2 surgically treating a heart valve.

1 5. The method of claim 4 further comprising the step of removing at least a
2 portion of the heart valve by means of a cutting tool introduced through a percutaneous
3 intercostal penetration and through the internal penetration.

1 6. The method of claim 4 further comprising the step of introducing a
2 replacement valve through a percutaneous intercostal penetration and through the
3 internal penetration into the internal cavity.

1 7. The method of claim 6 further comprising fastening the replacement
2 valve within the internal cavity by means of an instrument introduced through a
3 percutaneous intercostal penetration and through the internal penetration.

1 8. The method of claim 6 wherein the replacement valve is introduced
2 through a cannula positioned in a percutaneous intercostal penetration.

1 9. The method of claim 4 wherein a percutaneous intercostal penetration is
2 created in a right lateral portion of the patient's chest.

1 10. The method of claim 9 wherein the internal penetration is made in a wall
2 of the patient's left atrium.

1 11. The method of claim 10 wherein the heart valve comprises a mitral
2 valve.

1 12. The method of claim 10 wherein the heart valve comprises an aortic
2 valve.

1 13. A method of closed-chest replacement of a heart valve in a patient's
2 heart, the method comprising:
3 establishing cardiopulmonary bypass;
4 arresting the patient's heart;
5 viewing the patient's heart through a scope extending through a percutaneous
6 intercostal penetration in the patient's chest;

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10 positioning a replacement valve through a percutaneous intercostal penetration
11 in the patient's chest and through the internal penetration into a chamber of the heart;
12 and
13 securing the replacement valve in a valve position in the heart.

1 15. The method of claim 13 wherein the heart valve comprises a mitral
2 valve, the valve position comprising a mitral valve position.

1 16. The method of claim 15 wherein the chamber comprises a left atrium of
2 the patient's heart.

1 17. The method of claim 13 wherein the percutaneous intercostal penetration
2 is disposed in a right lateral portion of the patient's chest.

1 18. The method of claim 13 further comprising the step of removing at least
2 a portion of the patient's heart valve using a cutting tool introduced through a
3 percutaneous intercostal penetration and through the internal penetration.

1 19. The method of claim 13 further comprising sizing the patient's heart
2 valve by means of a sizing instrument introduced through a percutaneous intercostal
3 penetration and through the internal penetration.

a visualization scope configured to pass through an intercostal space in the

1 30. The system of claim 28 wherein the replacement valve comprises an
2 annular portion for attachment to a valve annulus in the heart, the annular portion
3 having an outer diameter, wherein the lumen in the cannula has a cross-sectional height
4 at least equal to the outer diameter, and a cross-sectional width less than the width of

5 the intercostal space.

1 31. The system of claim 28 further comprising cutting means positionable
2 through a percutaneous intercostal penetration and through the internal penetration for
3 removing at least a portion of the patient's heart valve.

1 32. The system of claim 28 further comprising means positionable through a
2 percutaneous intercostal penetration and through the internal penetration for sizing a
3 valve annulus of the patient's heart valve.

1 33. The system of claim 32 wherein the sizing means comprises an
2 elongated shaft and sizing means at a distal end of the shaft, wherein the shaft and
3 sizing means may be introduced through a percutaneous intercostal penetration and
4 through the internal penetration to position the sizing means near the valve annulus.

1 34. The system of claim 28 further comprising means for introducing the
2 replacement valve into the patient's heart, the introducing means comprising an
3 elongated shaft having means at a distal end thereof for releasably holding the
4 replacement valve.

1 35. The system of claim 34 wherein the introducing means further
2 comprises means actuated from a proximal end of the shaft for pivoting the replacement
3 valve relative to the shaft from a first position for introduction through a percutaneous
4 intercostal penetration to a second position for attachment at the valve location.

1 36. The system of claim 28 wherein the means for securing the replacement
2 valve comprises means positionable through a percutaneous intercostal penetration for
3 suturing the replacement valve to a valve annulus at the valve location.

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1 37. The system of claim 36 further comprising organizing means for
2 maintaining sutures in spaced-apart positions outside of the chest cavity after the
3 sutures have been applied to the valve annulus.

1 38. The system of claim 37 wherein the organizing means is fixed to a
2 proximal end of a cannula disposed in a percutaneous intercostal penetration, the
3 cannula having a lumen through which the replacement valve may be introduced into
4 the chest cavity.

1 39. The system of claim 37 further comprising means on the organizing
2 means for maintaining tension on ends of the sutures to facilitate advancing the
3 replacement valve along the sutures into the patient's heart.

1 40. The system of claim 26 further comprising retraction means positionable
2 through an intercostal space in the patient's chest for opening the internal penetration in
3 the wall of the heart or great vessel.

1 41. The system of claim 26 wherein the interventional means is configured
2 to reach the interior of the heart or great vessel from a percutaneous penetration in a
3 right lateral portion of the patient's chest.

1 42. The system of claim 41 wherein the interventional means is at least
2 about 20 cm in length.

1 43. A percutaneous access cannula to facilitate closed-chest replacement of a
2 heart valve in a patient's heart, the access cannula comprising:
3 a cannula body configured for placement in an intercostal space in the patient's
4 chest, the cannula body having a distal end, a proximal end, and a lumen extending
5 therebetween, the lumen being configured to allow passage of a replacement valve

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6 therethrough; and

7 an obturator positionable in the lumen, the obturator having a cross-sectional
8 width less than the width of the intercostal space and a cross-sectional height greater
9 than the cross-sectional width.

1 44. The access cannula of claim 43 wherein the valve prosthesis has an
2 annular attachment portion with an outer diameter, the obturator having a cross-
3 sectional height at least equal to the outer diameter.

1 45. The access cannula of claim 43 wherein the cross-sectional height is
2 about 2 to 6 times the cross-sectional width.

1 46. The access cannula of claim 43 wherein the obturator has a generally
2 rectangular cross-section.

1 47. The access cannula of claim 43 wherein the obturator has a generally
2 oval cross-section.

1 48. The access cannula of claim 44 wherein the lumen in the cannula body
2 has a cross-sectional shape in an unstressed condition with a width less than the width
3 of the intercostal space and a height greater than the outer diameter of the valve
4 prosthesis.

1 49. The access cannula of claim 48 wherein the lumen has a generally
2 rectangular cross-section.

1 50. The access cannula of claim 48 wherein the lumen has a generally oval-
2 shaped cross-section.

1 51. The access cannula of claim 48 wherein the cross-sectional height of the
2 lumen is 2 to 6 times the cross-sectional width of the lumen.

1 52. The access cannula of claim 43 further comprising means at the
2 proximal end of the cannula body for retaining a plurality of sutures extending through
3 the lumen in a spaced apart relationship.

1 53. The access cannula of claim 52 wherein the suture retaining means
2 comprises a plurality of slots in the proximal end of the cannula body in
3 circumferentially spaced positions around the lumen.

1 54. The access cannula of claim 52 further comprising means at the
2 proximal end of the cannula body for maintaining tension on the sutures.

1 55. The access cannula of claim 54 wherein the means for maintaining
2 tension comprises an organizing ring having an interior passage through which the
3 sutures may extend and a plurality of means circumferentially spaced around the
4 passage for frictionally engaging the sutures.

1 56. The access cannula of claim 55 wherein the organizing ring comprises
2 an inner ring, an outer ring rotatably coupled to the inner ring, a first plurality of
3 apertures circumferentially spaced about the inner ring, and a second plurality of
4 apertures circumferentially spaced about the outer ring, the first and second plurality of
5 apertures being aligned when the outer ring is in a first rotational position, and non-
6 aligned when the outer ring is in a second rotational position.

1 57. A cannula system to facilitate surgical intervention in a patient's body
2 cavity, the cannula system comprising:
3 a cannula body having a distal end, a proximal end, and a lumen therebetween.

4 the lumen being configured for introduction of surgical instruments therethrough; and
5 organizer means at the proximal end of the cannula body for retaining a plurality
6 of sutures extending through the lumen from the body cavity in spaced apart positions
7 outside of the body cavity.

1 58. The cannula system of claim 57 wherein the cannula body is configured
2 for positioning in an intercostal space in the patient's chest.

1 59. The cannula system of claim 57 wherein the organizer means comprises
2 a first organizing ring having an interior passage and a plurality of suture retaining
3 means circumferentially spaced about the interior passage.

1 60. The cannula system of claim 59 wherein the first organizing ring is fixed
2 to the proximal end of the cannula body with the interior passage aligned with the
3 lumen.

1 61. The cannula system of claim 59 wherein the suture retaining means
2 comprise a plurality of slots in the organizing ring circumferentially spaced about
3 the interior passage.

1 62. The cannula system of claim 60 further comprising means at the
2 proximal end of the cannula body for maintaining the sutures in tension.

1 63. The cannula system of claim 62 wherein the means for maintaining the
2 sutures in tension comprises a second organizing ring spaced apart from the first
3 organizing ring, the second organizing ring having an interior passage and a plurality of
4 means circumferentially spaced about the interior passage for holding the sutures in
5 tension.

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70. The thoracoscopic device of claim 68 further comprising means for pivoting the replacement valve relative to the handle from a first orientation for introduction through the intercostal space, to a second orientation for placement in the

4 valve position.

1 71. The thoracoscopic device of claim 68 wherein the pivoting means
2 includes an actuator disposed at the proximal end of the handle.

1 72. The thoracoscopic device of claim 68 further comprising means at the
2 proximal end of the handle for releasing the replacement valve from the holding means.

1 73. A prosthesis assembly for closed-chest replacement of a heart valve, the
2 prosthesis assembly comprising:

3 a replacement valve having an annular attachment portion and a movable valve
4 portion coupled to the attachment portion; and

5 holder means releasably mounted to the attachment portion, wherein the holder
6 means is configured to allow introduction of the replacement valve through an
7 intercostal space in the patient's chest.

1 74. The prosthesis assembly of claim 73 wherein the intercostal space has
2 an intercostal width, the replacement valve and holder means together having a profile
3 with a width less than the intercostal width.

1 75. The prosthesis assembly of claim 74 wherein the attachment portion of
2 the replacement valve has an outer diameter which is greater than the intercostal width.

1 76. The prosthesis assembly of claim 73 wherein the holder means
2 comprises an elongated handle having a distal end mounted to the replacement valve
3 and a proximal end opposite the distal end, the handle being configured for introducing
4 the replacement valve into the patient's heart through the intercostal space.

1 77. The prosthesis assembly of claim 76 wherein the handle is at least about

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